

RADIATION PHYSICS NOTE #17  
E100 SOIL STUDIES  
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The amount of leachable radioactivity that may be produced in the surrounding soil is one of the parameters that is used in the design of enclosures at Fermilab. The primary method used in studying this problem is to model the experimental set up with a Monte Carlo computer program. In the course of such a study of E100 in the Neutrino area, comparison was made between the soil activation predicted around E100 by the Monte Carlo program in general use at the Laboratory (A. Van Ginneken's program CASIM) and experimental results from soil corings and foils. Enclosure 100 was chosen as the site for this study since there were plans for its redesign. Enclosure 100 contains a target used to produce secondary beams for the bubble chambers. This area was designed as a low intensity station since the bubble chamber can not use many particles. However, there have been several schemes advanced which would yield enriched beams of strange particles for the bubble chambers. These schemes would entail higher intensities on target in E100. Hence, Monte Carlo studies were made to investigate the effect that increased shielding would have upon the radioactivation of the soil, and studies were made of the accuracy of the Monte Carlo program itself.

In order to model an experimental set up, the details of the geometry need to be entered into the Monte Carlo. The relevant aspects of this problem are the details of E100 downstream of

the hadron target and the location of two holes in the shielding berm which were drilled downstream of E100. Figure 1 is a sketch of the downstream end of E100 and the X's denote where the holes were bored. The area of interest contains a target, two bending magnets, and a beam dump.

The Monte Carlo program used was A. Van Ginneken's program CASIM and the geometry routine was originally set up by him. All magnetic fields were ignored, but the primary beam was dumped at the proper angle. For the most precise comparison of the Monte Carlo to experimental data, activation foils were placed in the holes along with soil. During this particular run the primary beam momentum was 300GeV/c and the target was between the two bending magnets instead of upstream of both. During the time that the foils were in the soil we integrated the number of protons on target ( $1.5 \times 10^{16}$ ). Hence, not only do we have a Monte Carlo prediction, but we have direct measurement of protons on target and the resulting activation in the soil.

The comparison between the Monte Carlo and the data is shown in figure 2. There is an apparent shift in the peak positions in the Monte Carlo results. However, considering the statistical accuracy of the Monte Carlo the rough agreement in magnitude and position is adequate. Additional data were accumulated over a nine month period during which the targeting conditions were different and the temporal variations were much greater than in the more controlled run. These results are presented in the dashed lines in figure 2, and allowing for the differing conditions the experimental results are consistent (except for the two deepest foils in hole #1).

There is fair agreement between the Monte Carlo predictions and the results from the foils which were mounted on the inside of E100 (see figure 3). However, a portion of the activation of the horizontal foils is due to the operations of the adjacent muon line. If we take this contamination into account, we note that the Monte Carlo is significantly higher than the foils. This discrepancy can be qualitatively understood by noting that the hadron momentum spectrum at the wall is harder than the momentum spectrum in the holes. This implies that the average activation cross section at the wall is lower than that in the holes, hence using the same cross section for both locations in the Monte Carlo estimate will cause the calculated activation at the wall to be relatively higher than that at the holes. The proper cross section to use is difficult to determine properly, but incorporating this change in cross section will decrease the Monte Carlo predictions at the wall.

The usual monitoring of soil activation is done by foils on the inside of an enclosure. The activation of the outside soil is then estimated by using CASIM. Hence, this experiment is important because it checks the normal monitoring procedure and also it gives a direct relation between foil activation on the inside of an enclosure and foil activation in the soil downstream of the enclosure.

Finally we examine the activation the soil samples which were taken from the hole itself. There results are presented

in figure 4. There is no comparable beam monitoring for these results, hence normalization of the Monte Carlo results is not possible. One can work backwards to calculate a flux using figure 7 of Tm 283, i.e. we use a value of  $1.2 \times 10^{-4} \text{ cm}^2/\text{gm}$  for the macroscopic excitation function of  $^{22}\text{Na}$  in soil. Using the maximum at hole #2 to compare soil and Monte Carlo we obtain an incident flux of  $6.5 \times 10^{16}$  protons. This is a reasonable estimate for the amount of beam incident on target up to this time.

The results given above have indicated the pattern of activity at a given geometrical location. However, the quantity of interest in designing enclosures is the total amount of activation in the soil. As a design aid it is also useful to examine the pattern of activation in the soil due to each beam line element. Differing beam line configurations for E100 were studied and on the bottom of the next two figures a schematic representation of the particular beam line configuration is given. Figure 5 depicts the normal situation in E100, i.e. a target, two bending magnets, and a dump. In contrast to this situation, figure 6 shows the hypothetical situation when the entire region from the target to an iron backwall, extending 25 feet deep, was filled with an 18" radius of iron sheath. This amount of shielding is the practicable upper limit on the amount of shielding which can go into E100. The graphs show how the pattern of activation reduces with the increased shielding. The graphs indicate that the maximum star density occurs downstream of the dump. However, comparing the pattern of soil activation upstream of the dump in the two different configurations indicates that simply increasing the size of the

dump is necessary but not sufficient to reduce the activation in the soil. The number of stars in soil/(incident proton) for the two cases are respectively 37 and 2.8. The latter number is too small since practically speaking one would not turn the entire backwall into Fe, nor would one have it extend for 25 feet. From plots of the star distribution in the backwall one can estimate that a 4'x6'x6' section would capture 80% of the stars in the backwall. This increases the number of stars in soil/(incident proton) for the second case to 3.8.

P. Gollon has estimated on geological and hydrological grounds (using TM-292) the maximum permissible number of stars in unprotected soil/second to be  $1.5 \times 10^{11}$ . Assuming a ten second repetition rate this implies  $1.5 \times 10^{12}$  stars in soil/pulse. In the normal studies above we had 37 stars in soil/(incident proton), this implies that the number of protons/pulse should not exceed  $4 \times 10^{10}$ . This is consistent with the present limitation of  $5 \times 10^{10}$  proton/pulse. For the second case studied above (the 18"Fe sheath) we had 3.8 stars in soil/(incident proton), and this implies that the number of protons/pulse should not exceed  $4 \times 10^{11}$  proton/pulse.

We have shown that the Monte Carlo program can give quantitative results about soil activation which are in reasonable agreement with experimental data. Examples of the use of this program to study experimental configurations were presented. These examples demonstrated that the present configuration of El00 is adequate for the present intensity limit of  $5 \times 10^{10}$  protons/pulse, and possible design changes were studied which would allow increased intensities.



NATIONAL ACCELERATOR LABORATORY

## ENGINEERING NOTE

SECTION

PROJECT

SERIAL-CATEGORY

PAGE

SUBJECT

NAME

DATE

REVISION DATE

PLAN VIEW OF E100

T<sub>92</sub>

7 BOOT

3 BOOT

Dump

Hole #2

Hole #1

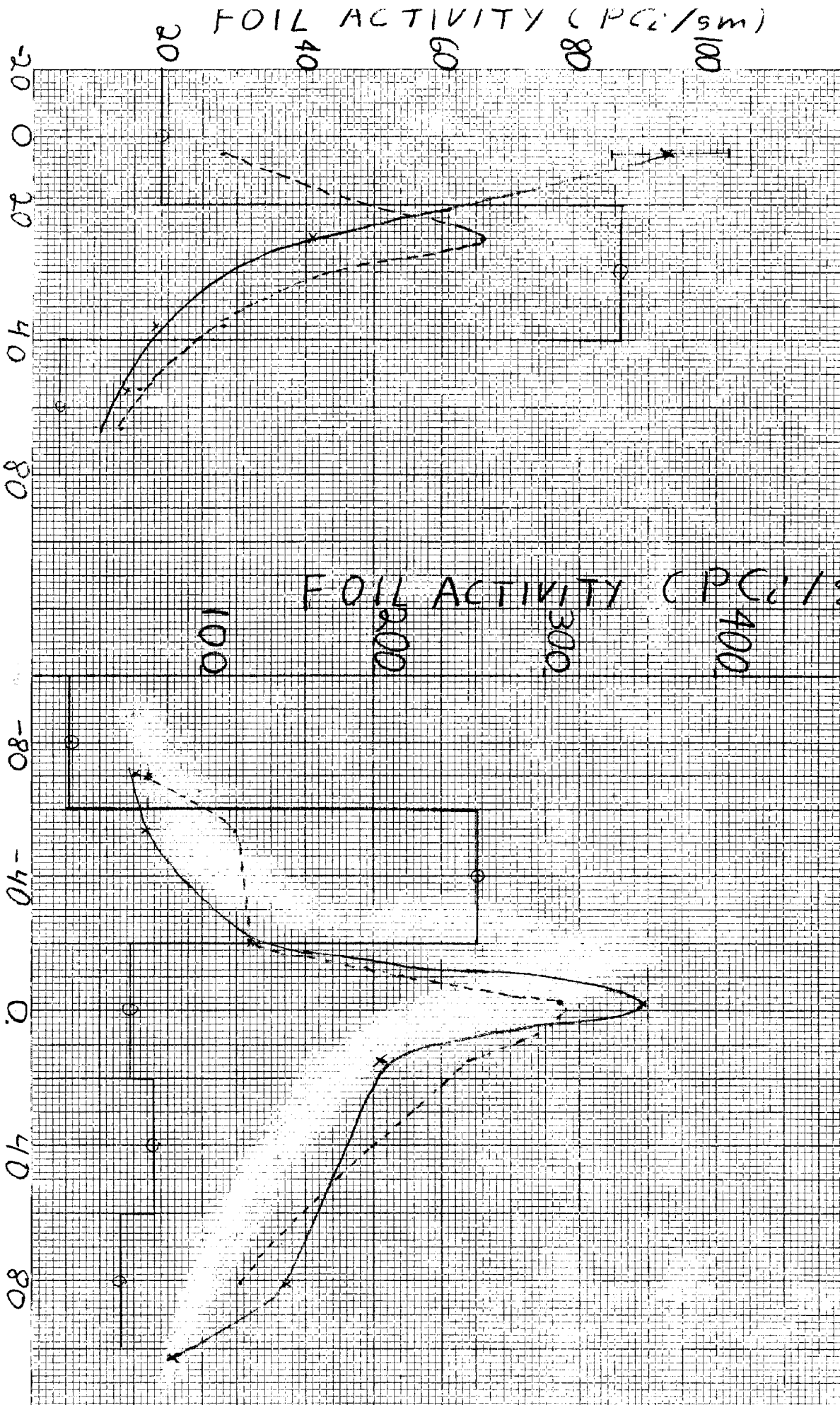
0 1  
1" = 8'

FIGURE 2

\* FOIL RESULTS ONE MONTH PERIOD  
 --- FOIL RESULTS NINE MONTH PERIOD  
 o MONTE CARLO ONE MONTH PERIOD

HOLE #1

HOLE #2



VERTICAL DISTANCE FROM BEAM (CM.)

46 1320

10 X 10 TO 1/2 INCH 7 X 10 INCHES  
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 3

FOIL DATA DOWNSTREAM WALL ELI00

MONTE CARLO  
FOIL

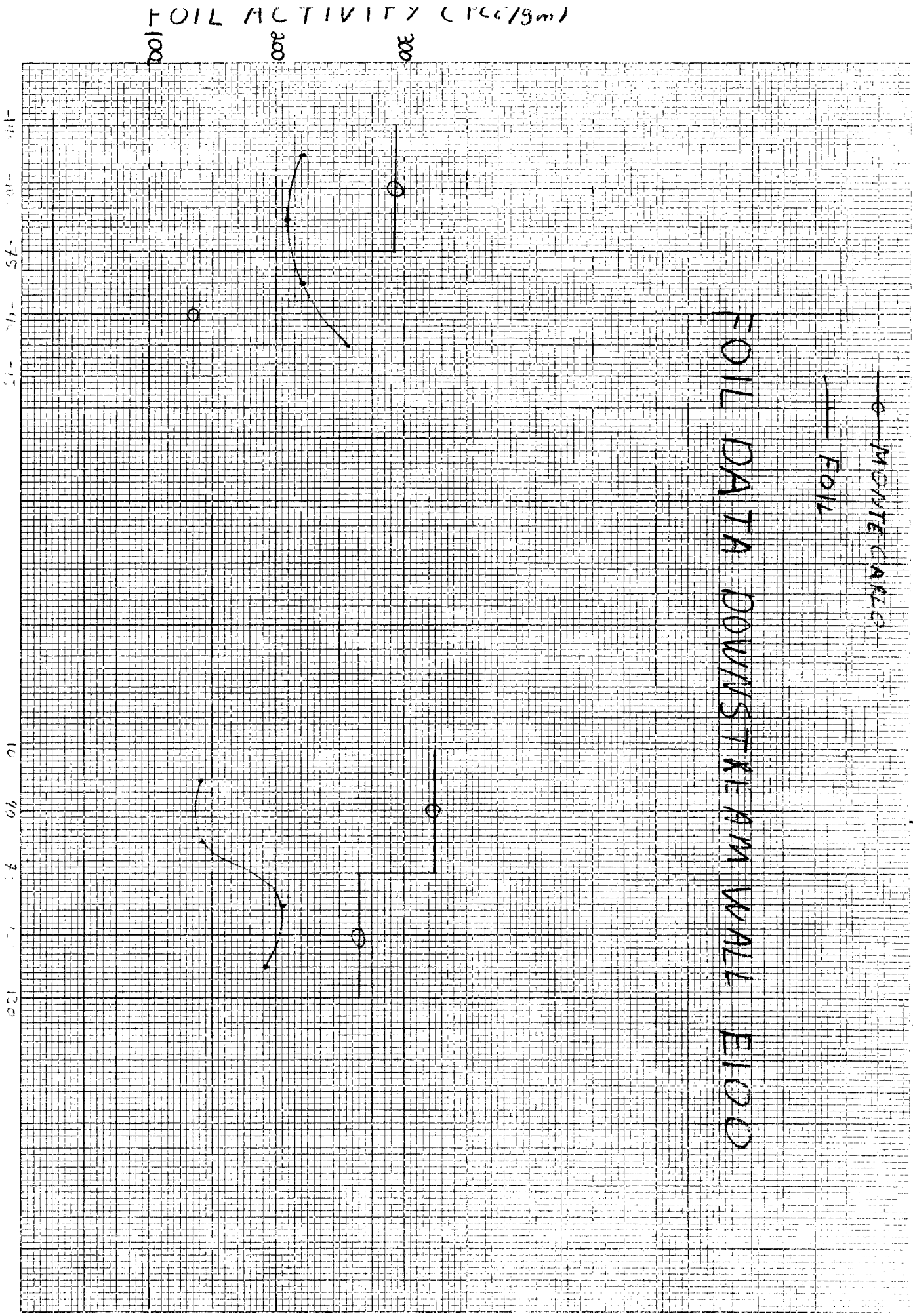




Figure 4

K&E 10 X 10 TO 1/2 INCH 7 X 10 INCHES  
KEUFFEL & ESSER CO. MADE IN U.S.A.  
46 1320  
SOIL ACTIVITY (PCi/5m)

100

HOLE #1

○ MONTE CARLO  
(ARBITRARY NORMALIZATION)

--- SOIL

50

0

HOLE #2

400

300

200

100

0

-80

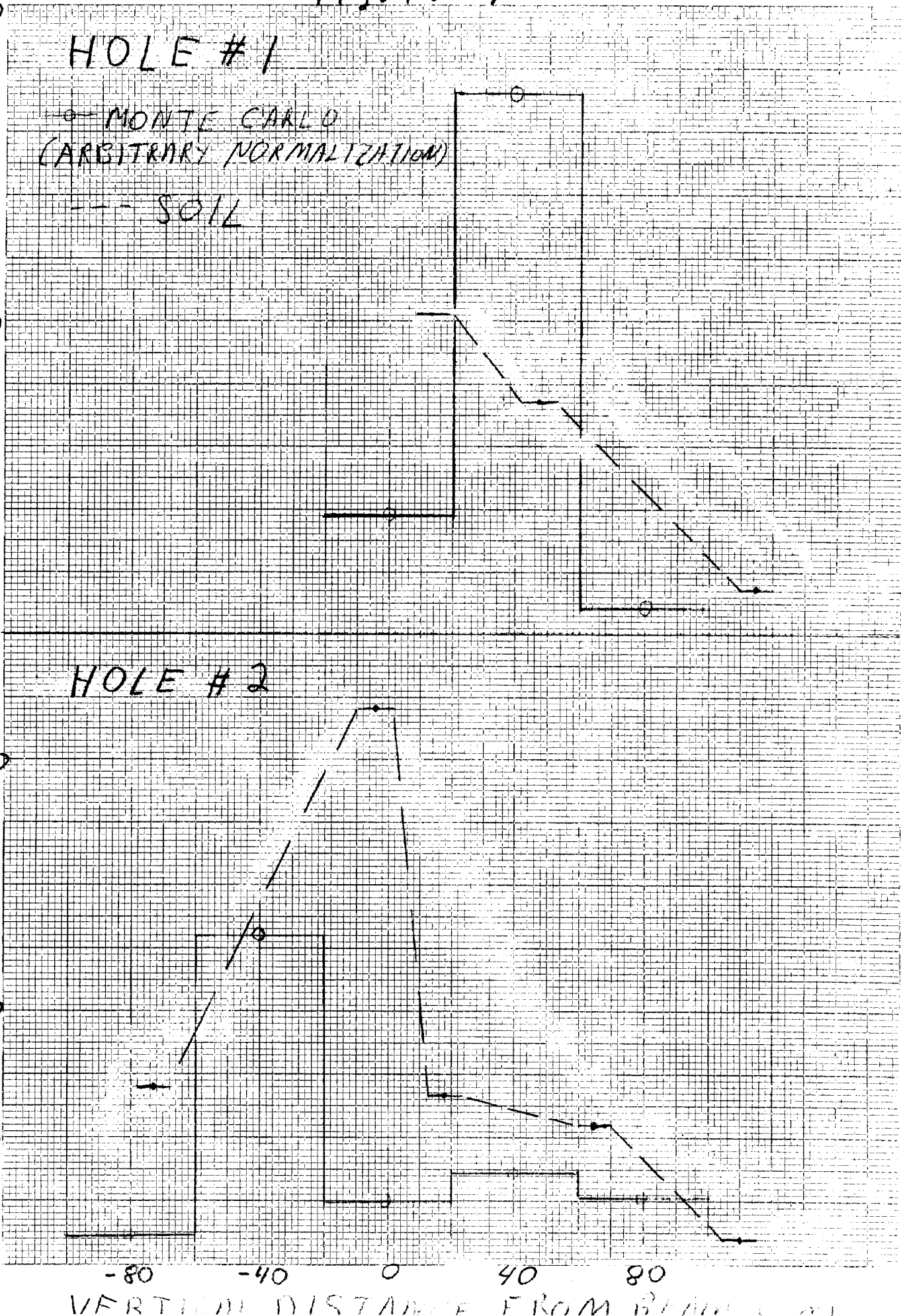
-40

0

40

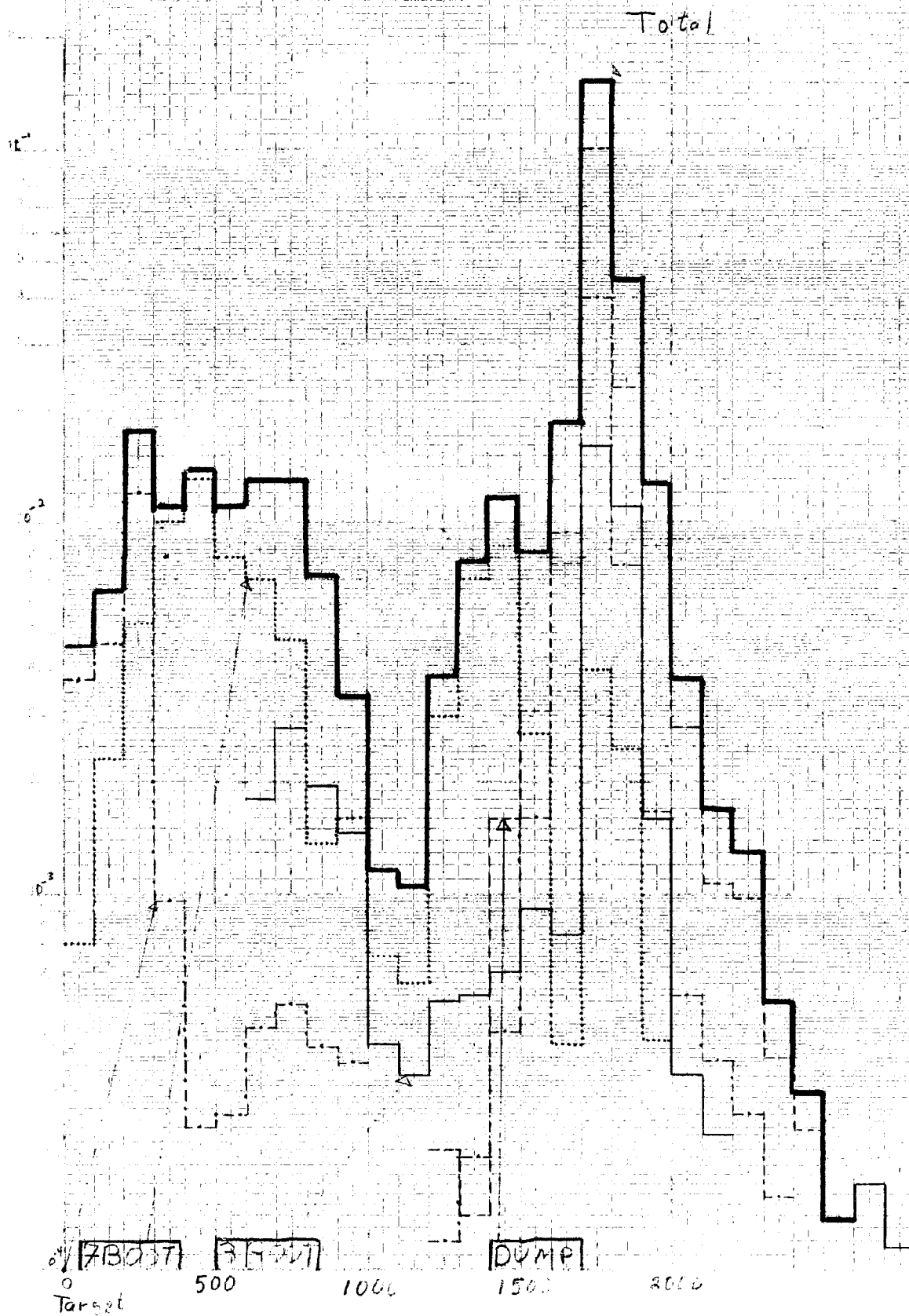
80

VERTICAL DISTANCE FROM BEAM (cm)



# FIGURE 5

Stars in soil  
cm \* inc. Protons



E100 18" Sheath

FIGURE 6

Stars in soil  
cut \* inc. protein

